ELASTIC SCATTERING OF SPIN-POLARIZED ELECTRONS FROM SPIN-POLARIZED Na ATOMS

M.H. Kelley, J.J. McClelland and R.J. Celotta

National Bureau of Standards, Gaithersburg, MD USA

As part of an ongoing program of state-selected electron-atom scattering experiments, we have measured the angular dependence of exchange effects in low energy elastic electron scattering from a spin-polarized one-electron target. The spin-polarized electrons were obtained from a GaAs source,[1] and the Na atoms were polarized via optical pumping.[2] Four intensities were measured - $I^{\uparrow\uparrow}$, $I^{\uparrow\downarrow}$, $I^{\downarrow\uparrow}$ and $I^{\downarrow\downarrow}$ (the first arrow refers to the electron spin and the second to the atomic spin). These were combined into an "antiparallel minus parallel" asymmetry as follows:

$$A^{exch} = \frac{1}{P_e P_a} \frac{(I^{\uparrow\downarrow} + I^{\downarrow\uparrow}) - (I^{\uparrow\uparrow} + I^{\downarrow\downarrow})}{(I^{\uparrow\downarrow} + I^{\downarrow\uparrow}) + (I^{\uparrow\uparrow} + I^{\downarrow\downarrow})},$$

where P_e and P_a are the electron and atom polarizations, respectively. The results for an incident energy of 54.4 eV are shown in Figure 1.

In conducting these studies, we found the additional surprising result that the spin-orbit interaction also produces a measurable effect. This was unexpected because of the relatively low incident electron energy and the light target (Z=11). The effect was seen by constructing an asymmetry which averages over the polarization of the atom:

$$A^{s-o} = \frac{1}{P_e} \frac{(I^{\uparrow\downarrow} + I^{\uparrow\uparrow}) - (I^{\downarrow\uparrow} + I^{\downarrow\downarrow})}{(I^{\uparrow\downarrow} + I^{\uparrow\uparrow}) + (I^{\downarrow\uparrow} + I^{\downarrow\downarrow})}.$$

This asymmetry is shown in Figure 2.

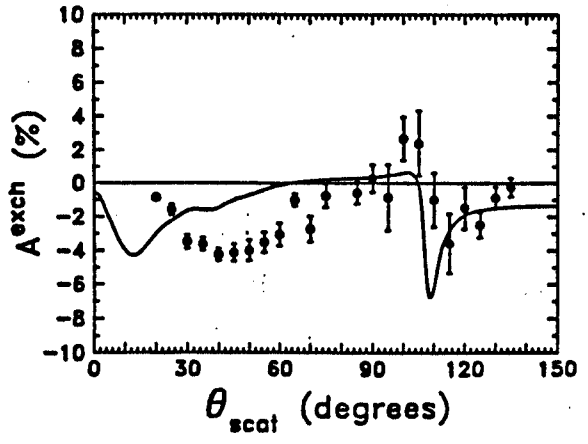

Figure 1. A^{exch} vs θ_{scat}. Incident energy is 54.4 eV.

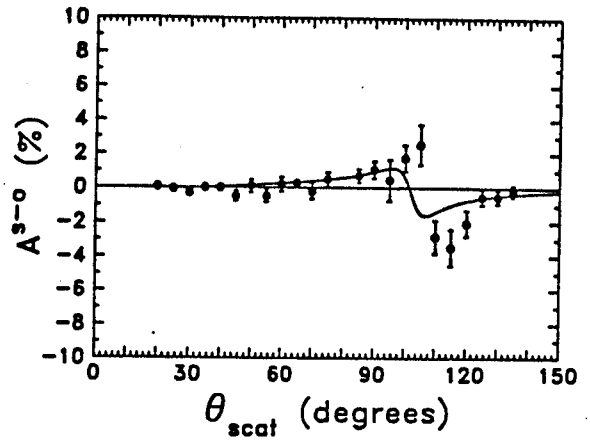

Figure 2. A^{s-o} vs θ_{scat}. Incident energy is 54.4 eV.

These two measurements provide an excellent test for theories which attempt to simultaneously include exchange and spin-orbit effects. That both asymmetries are non-zero indicates that a truly accurate theory must take both effects into account. Nevertheless, one can still compare a theory including only exchange with A^{exch}, or a theory containing only spin-orbit with A^{s-o}. This we have done in the figures; the solid line in Figure 1 is a two-state close-coupling calculation from Reference 3, and the solid line in Figure 2 is a relativistic static-potential calculation from Reference 4.

Though there are some clear differences between theory and experiment, general qualitative agreement is found in each case. This will hopefully provide a stimulus for further investigation into the behavior of electron scattering when both spin-orbit and exchange effects are significant.

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References.

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